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ABSTRACT

The NCTM Standards call for the introduction of challenging mathematics content for all students beginning in the early grades. If teachers are to guide students in their exploration of mathematics concepts, they must themselves have a firm grasp of powerful mathematics concepts. This paper uses data from the 1993 National Survey of Science and Mathematics Education and focuses on results in relation to teacher preparation, teacher pedagogical beliefs, teacher perceptions of their preparation, and the school as a collegial work place envisioned by the NCTM Standards documents. Results showed that while elementary teachers tend to be confident of their ability to use reform-oriented strategies, such as cooperative learning, they are not well prepared to teach a number of mathematics content areas recommended for the early grades. In contrast, high school teachers are more likely to have extensive preparation in mathematics, but are less supportive of the use of reform-oriented instructional techniques and less confident of their ability to do so. Increased opportunities for high quality inservice education and substantial changes in preservice education are essential to meet the needs of the many mathematics teachers who are not prepared to implement the NCTM Standards. (MKR)

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Mathematics Teachers' Response to the Reform Agenda

Results of the 1993 National Survey of Science and Mathematics Education

by

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Mathematics Teachers' Response to the Reform Agenda

A. Introduction

The 1993 National Survey of Science and Mathematics Education is based on a national probability sample of science and mathematics program heads and teachers in grades 1–12 in the 50 states and the District of Columbia. The sample was designed to allow national estimates of science and mathematics course offerings and enrollment; teacher background preparation; textbook usage; instructional techniques; and availability and use of science and mathematics facilities and equipment. Every eligible school and teacher in the target population had a known, positive probability of being drawn into the sample.

This paper focuses on teacher preparation and support for teaching mathematics as envisioned in the National Council of Teachers of Mathematics (NCTM) *Standards*.

B. Teacher Preparation

The NCTM *Standards* call for the introduction of challenging mathematics content to all students beginning in the early grades. If teachers are to guide students in their exploration of mathematics concepts, they must themselves have a firm grasp of powerful mathematics concepts.

Because it would be extremely difficult to gauge the extent to which a large national sample of teachers understands mathematics concepts (and knows how to help their students learn these concepts), proxy measures such as major or number of courses taken in the field are typically used. Table 1 shows that very few grade 1–4 teachers had undergraduate majors in mathematics or mathematics education. (Roughly 80 percent majored in elementary education.) While mathematics teachers in grades 5–8 were more likely than their grade 1–4 colleagues to have undergraduate majors in mathematics, a majority still had majors in education.

Table 1
Mathematics Teacher Undergraduate Majors

	Percent of Teachers		
	Grades 1–4	Grades 5–8	Grades 9–12
Mathematics	1	7	41
Mathematics Education	0	3	18
Other Education	89	71	20
Other Fields	11	20	22

Grade 9–12 mathematics teachers were more likely to have majored in mathematics (41 percent) than in mathematics education (18 percent). While the percentages of teachers with majors in field are greater for grades 9–12 than for the lower grades, still roughly 4 out of 10 high school mathematics teachers did not major in their field at either the undergraduate or graduate level and nearly 1 in 5 grade 9–12 mathematics teachers did not have even a minor in the field. (See Table 2.)

Table 2
Mathematics Teachers' Majors and Minors in Mathematics and Mathematics Education

	Percent of Teachers		
	Grades 1–4	Grades 5–8	Grades 9–12
Undergraduate major in mathematics	1	7	41
Undergraduate or graduate major in mathematics/mathematics education	1	11	63
Undergraduate or graduate major or minor in mathematics/mathematics education	7	18	81

As can be seen in Table 3, 83 percent of grade 9–12 mathematics teachers have had at least eight semesters of coursework in mathematics, compared to 8 percent of those teaching in grades 1–4. It is interesting to note that while only 20 percent of grade 5–8 mathematics teachers have had eight or more semesters of college mathematics, 32 percent of grade 5–8 mathematics *classes* are taught by these teachers, a reflection of the fact that teachers in grades 7 and 8 are generally both better prepared than teachers in grades 5 and 6 and are more likely to teach multiple mathematics classes each day.

Table 3
Number of Semesters* of College Coursework in Mathematics

	Percent of Mathematics Teachers			Percent of Mathematics Classes		
	Grades 1–4	Grades 5–8	Grades 9–12	Grades 1–4	Grades 5–8	Grades 9–12
< 4 Semesters	80	62	4	80	48	3
4–7 Semesters	13	19	12	13	20	10
8–11 Semesters	6	13	45	6	20	46
> 11 Semesters	2	7	38	1	12	41

* Since the highest number of semesters a teacher could indicate for "calculus" and for "all other mathematics courses" was "8," these figures underestimate the total for any teacher who completed more than eight courses in a particular category.

C. Teacher Pedagogical Beliefs

The National Council of Teachers of Mathematics published *Curriculum and Evaluation Standards* in 1989 and *Professional Standards for Teaching Mathematics* in 1991. As one measure of the influence of the NCTM *Standards*, mathematics teachers in the 1993 National Survey of Science and Mathematics Education were asked the extent of their familiarity with each of these documents. As can be seen in Table 4, mathematics teachers in the higher grades are much more likely than their counterparts in the lower grades to report that they are familiar with the two standards documents. Roughly 1 in 5 elementary mathematics teachers, 1 in 4 middle grade mathematics teachers, and 1 in 2 high school mathematics teachers indicated they were "well aware" of the *Curriculum and Evaluation Standards*. Not surprisingly, teachers in each grade range are less likely to be familiar with the more recently released *Professional Standards for Teaching Mathematics*.

Table 4
Mathematics Teachers' Familiarity with the NCTM *Standards*

	Percent of Teachers		
	Grades 1–4	Grades 5–8	Grades 9–12
Curriculum and Evaluation Standards			
Well aware of the NCTM *Standards*	18	28	56
Heard of the NCTM *Standards*, but don't know much about them	39	41	33
Not aware of the NCTM *Standards*	30	22	8
Not sure	13	9	3
Professional Standards for Teaching			
Well aware of the NCTM *Teaching Standards*	12	19	40
Heard of the NCTM *Teaching Standards*, but don't know much about them	38	48	44
Not aware of the NCTM *Teaching Standards*	38	25	13
Not Sure	13	8	3

Those teachers who indicated they were "well aware" of each set of standards were asked to indicate the depth of their knowledge. As can be seen in Table 5, roughly 90 percent of the teachers in each grade range who said they were well aware of a particular set of standards indicated they were well informed about them for the grades they teach, and one-half or more said they were prepared to explain the *Standards* to their colleagues.

Table 5
Mathematics Teachers' Reported Understanding of the NCTM *Standards*

	Percent of Teachers Agreeing*		
	Grades 1–4	Grades 5–8	Grades 9–12
Curriculum and Evaluation Standards			
I am well informed about the NCTM *Standards* for the grades I teach	87	88	91
I am prepared to explain the NCTM *Standards* to my colleagues	50	53	58
Professional Standards for Teaching			
I am well informed about the NCTM *Teaching Standards* for the grades I teach	90	91	89
I am prepared to explain the NCTM *Teaching Standards* to my colleagues	57	49	55

* Only teachers who indicated they were "well aware" of each set of standards were asked to respond to these items. These percentages include teachers who responded "strongly agree" or "agree."

Of course, whether or not they are knowledgeable about the documents, mathematics teachers may or may not agree with the principles underlying the NCTM *Standards* or the recommendations that flow from them. The *Standards* stress the need to involve all students in learning important and powerful mathematics concepts from the earliest grades; deemphasizing, for example, arithmetic computation in favor of having students develop reasoning and problem-solving abilities. Tracking and other school and district policies that prevent some students from having the opportunity to learn challenging mathematics content are to be discontinued.

Moreover, reform advocates stress that all students need to be actively engaged in learning mathematics—using manipulatives to investigate mathematics concepts; using calculators, computers, and other technologies to explore mathematics concepts; and working with their peers in cooperative learning groups. The teacher should be a guide rather than simply a dispenser of information, and should use a variety of strategies to assess student learning, rather than relying primarily on paper and pencil, multiple-choice tests.

To get an idea of teachers' beliefs as they relate to reforms suggested by the NCTM *Standards*, teachers were asked if they agreed with a number of statements about mathematics education. The results show that while most teachers believe that "virtually all students can learn to think mathematically," sizable proportions believe that such learning is best accomplished by placing students in classes with students of similar abilities. Support for homogeneous grouping is stronger in the higher grades, with 76 percent of grade 9–12 teachers indicating that students learn mathematics best in classes with students of similar abilities, compared to 41 percent of those in grades 1–4 and 62 percent of those in grades 5–8. (See Table 6.)

Table 6
Mathematics Teachers' Opinions on Curriculum and Instruction Issues

	Percent of Teachers Agreeing*		
	Grades 1–4	Grades 5–8	Grades 9–12
Students learn best when they study mathematics in the context of a personal or social application	94	91	84
Virtually all students can learn to think mathematically	76	76	72
Students learn mathematics best in classes with students of similar abilities	41	62	76
Students need to master arithmetic computation before going on to algebra	70	77	81
The testing program in my state/district dictates what mathematics I teach	60	52	40
Students should be able to use calculators most of the time	24	39	73
Activity-based experiences aren't worth the time and expense for what students learn	5	8	9

* Includes teachers indicating "strongly agree" and "agree" to each statement.

Mathematics teachers are supportive of the importance of teaching in the context of personal and social applications, but they voiced considerable resistance to another of the tenets of current reform ideas. While the NCTM *Curriculum and Evaluation Standards* argue for the earlier introduction of algebraic concepts, the majority of elementary, middle, and high school mathematics teachers indicated their belief that "students must master arithmetic computations before going on to algebra." Support for the frequent use of calculators, another emphasis of the NCTM *Standards*, was quite high among high school mathematics teachers, with 73 percent indicating that "students should be able to use calculators most of the time"; mathematics teachers in the lower grades were less likely to support such extensive use of calculators.

In another attempt to gauge teacher support for reform recommendations, mathematics teachers were provided with a list of instructional "strategies" and asked how important they believed each was for effective mathematics instruction. Again, it is clear that mathematics teachers support some of the current reform notions, but are less convinced about others.

Table 7 shows the percent of mathematics teachers rating each strategy a five on a five-point scale ("definitely should be a part of mathematics instruction") at the grade level they teach. (Table 8 shows the analogous data combining ratings of four and five.) Note that pedagogical beliefs among mathematics teachers vary considerably by grade taught. For example, more than 80 percent of grade 1–4 mathematics teachers, but only 1 in 2 in grades 5–8 and 1 in 4 in grades 9–12 consider the use of hands-on/manipulative activities to be essential for effective mathematics instruction. Teachers in the higher grades are similarly less likely to consider essential such strategies as concrete experiences before abstract treatments; applications of mathematics in daily life; having students work in cooperative learning groups; use of computers; and taking students' prior conceptions about a topic into account when planning curriculum and instruction. In contrast, high school teachers are more likely than their colleagues in the elementary grades to consider the use of calculators essential for effective mathematics instruction.

Table 7
Mathematics Teachers Indicating that Various Strategies Definitely Should be a Part of Mathematics Instruction

	Percent of Teachers		
	Grades 1–4	Grades 5–8	Grades 9–12
Hands-on/manipulative activities	82	49	26
Concrete experience before abstract treatments	81	55	33
Applications of mathematics in daily life	81	75	50
Emphasis on solving real problems	80	78	57
Every student studying mathematics each year	76	69	38
Emphasis on mathematical reasoning	69	64	58
Emphasis on connections among concepts	68	62	52
Students working in cooperative learning groups	58	41	27
Use of computers	52	39	34
Emphasis on arithmetic computation	49	36	22
Coordination of mathematics with science	34	27	22
Taking student preconceptions about a topic into account when planning curriculum/instruction	34	26	18
Use of calculators	33	37	50
Inclusion of performance-based assessment	33	29	18
Deeper coverage of fewer mathematics ideas	33	31	16
Emphasis on writing about mathematics	32	23	20
Integration of mathematics subjects (e.g., algebra, probability, geometry, etc.) all taught together each year	26	25	20
Coordination of mathematics with vocational/technology education	25	23	19

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Table 8
Mathematics Teachers Indicating that Various Strategies Are an Important Part of Mathematics Instruction*

	Percent of Teachers		
	Grades 1–4	Grades 5–8	Grades 9–12
Emphasis on solving real problems	99	99	98
Applications of mathematics in daily life	99	99	95
Emphasis on mathematical reasoning	98	98	98
Emphasis on connections among concepts	98	98	97
Hands-on/manipulative activities	98	89	78
Every student studying mathematics each year	97	96	81
Concrete experience before abstract treatments	97	92	85
Students working in cooperative learning groups	92	82	78
Emphasis on arithmetic computation	90	89	64
Use of computers	87	87	81
Inclusion of performance-based assessment	82	78	71
Coordination of mathematics with science	81	75	80
Taking student preconceptions about a topic into account when planning curriculum/instruction	79	80	67
Deeper coverage of fewer mathematics ideas	72	75	55
Use of calculators	71	80	89
Emphasis on writing about mathematics	71	64	60
Integration of mathematics subjects (e.g., algebra, probability, geometry, etc.) all taught together each year	64	65	56
Coordination of mathematics with vocational/technology education	62	73	75

* Teachers were given a five-point scale for each strategy, with 1 labeled "definitely should not be a part of science instruction"; 3, "makes no difference"; and 5, "definitely should be a part of mathematics instruction." These numbers represent the total circling 4 or 5.

D. Teacher Perceptions of Their Preparation

Elementary teachers are typically assigned to teach science, mathematics, and other academic subjects to one group of students, but it is clear that they do not feel equally qualified to teach these subjects. Table 9 shows the percent of self-contained elementary teachers perceiving themselves to be "very well qualified" to teach reading/language arts, social studies, mathematics, and science at three different points in time—1977, 1985–86, and 1993. In 1993, 76 percent of elementary teachers assigned to teach all four subjects indicated they felt very well qualified to teach reading/language arts, compared to roughly 60 percent for both mathematics and social studies, but only 26 percent for life sciences.

Table 9
Self-Contained Grade 1–6 Teachers Feeling Very Well Qualified to Teach Each Subject: 1977, 1985–86, and 1993

	Percent of Teachers		
	1977*	1985–86	1993
Reading/Language Arts	63	86	76
Mathematics	49	69	60
Social Studies	39	51	61
Life Sciences	--	27	26
Science	22	--	--

* 1977 figures include Kindergarten teachers.

Mathematics teachers were also given a list of 14 mathematics topics recommended by the NCTM *Curriculum and Evaluation Standards* for one or more of the grade ranges 1–4, 5–8, and 9–12 and asked to indicate how well qualified they felt to teach each one at the grade level they teach. As can be seen in Table 10, the only topics which a majority of grade 1–4 mathematics teachers feel very well qualified to teach are number sense and numeration (66 percent); patterns and relationships (58 percent); measurement (54 percent); and estimation (50 percent). Only 1 in 10 grade 1–4 teachers feels very well qualified to teach probability and statistics, topics that are recommended by the NCTM *Standards* for grades 1–4.

Table 10
Grade 1–4 Mathematics Teachers' Ratings of Their Qualifications to Teach Each of a Number of Topics

	Percent of Teachers		
	Not Well Qualified	Adequately Qualified	Very Well Qualified
Estimation	3	47	50
Number sense and numeration	1	33	66
Number systems and number theory	9	47	44
Measurement	3	44	54
Fractions and decimals	6	47	47
Geometry and spatial sense	9	49	42
Functions	14	50	36
Patterns and relationships	3	39	58
Algebra	42	41	17
Trigonometry	70	24	5
Probability and statistics	50	39	11
Discrete mathematics	64	31	5
Conceptual underpinnings of calculus	80	17	2
Mathematical structure	55	38	7

In grades 5–8 (see Table 11), a majority of mathematics teachers feels very well qualified to teach each of seven topics: fractions and decimals (81 percent); number sense and numeration (71 percent); estimation (64 percent); measurement (60 percent); number systems and number theory (58 percent); patterns and relationships (52 percent); and geometry and spatial sense (50 percent). Nearly that many feel very well qualified to teach functions (49 percent) and algebra (44 percent), but only 28 percent feel well qualified to teach probability and statistics.

Table 11
Grade 5–8 Mathematics Teachers' Ratings of Their Qualifications to Teach Each of a Number of Topics

	Percent of Teachers		
	Not Well Qualified	Adequately Qualified	Very Well Qualified
Estimation	3	33	64
Number sense and numeration	2	27	71
Number systems and number theory	5	37	58
Measurement	2	38	60
Fractions and decimals	0	19	81
Geometry and spatial sense	7	43	50
Functions	11	40	49
Patterns and relationships	2	46	52
Algebra	18	38	44
Trigonometry	59	28	13
Probability and statistics	27	46	28
Discrete mathematics	57	33	10
Conceptual underpinnings of calculus	73	24	4
Mathematical structure	46	41	14

As can be seen in Table 12, a majority of mathematics teachers in grades 9–12 feels very well qualified to teach each of 10 out of the 14 topics listed, ranging from 95 percent for algebra to 60 percent for trigonometry. In contrast, only about 3 out of 10 high school mathematics teachers feel well qualified to teach probability and statistics; mathematical structure; and the conceptual underpinnings of calculus; and only 2 out of 10 feel well qualified to teach discrete mathematics at the high school level.

Table 12
Grade 9–12 Mathematics Teachers' Ratings of Their Qualifications to Teach Each of a Number of Topics

	Percent of Teachers		
	Not Well Qualified	Adequately Qualified	Very Well Qualified
Estimation	2	27	72
Number sense and numeration	1	21	78
Number systems and number theory	2	30	67
Measurement	1	20	79
Fractions and decimals	0	7	93
Geometry and spatial sense	3	27	69
Functions	2	23	75
Patterns and relationships	1	28	71
Algebra	0	5	95
Trigonometry	10	30	60
Probability and statistics	14	54	33
Discrete mathematics	26	55	20
Conceptual underpinnings of calculus	33	38	29
Mathematical structure	19	51	30

Teachers in both the 1985–86 and 1993 national surveys were asked about their enjoyment of mathematics teaching and whether or not they consider themselves to be "master" teachers. As can be seen in Table 13, in 1993, more than 95 percent of grade 1–6, 7–9, and 10–12 mathematics teachers reported that they enjoy teaching these subjects. About half of all grade 1–6 mathematics teachers and more than two-thirds of those in grades 7–12 consider themselves to be "master" mathematics teachers.

Table 13
Mathematics Teachers' Opinions About Their Teaching: 1985–86 and 1993

	Percent of Teachers Agreeing*					
	1985–86			1993		
	Grades 1–6	Grades 7–9	Grades 10–12	Grades 1–6	Grades 7–9	Grades 10–12
Consider themselves "master" teacher of mathematics	44	60	68	49	69	77
Enjoy teaching mathematics	93	98	97	96	98	98

* Includes teachers indicating "strongly agree" and "agree" to each statement.

Mathematics teachers were also asked how well prepared they felt for each of a number of tasks they might be expected to accomplish as part of their teaching responsibilities. Table 14 shows the percent of grades 1–4, 5–8, and 9–12 mathematics teachers indicating they were either "fairly well prepared" or "very well prepared" for each task.

Note that while greater use of technology is advocated as part of mathematics education reform, only from 43 to 51 percent of mathematics teachers in the various grade ranges feel at least fairly well prepared to use computers as an integral part of instruction. (It is interesting to note that middle and high school mathematics teachers are more confident of their ability to use calculators as an integral part of instruction.)

The 1993 National Survey of Science and Mathematics Education also provided evidence that teachers do not feel well prepared to teach the diversity of students in our nation's schools. On the positive side, the vast majority of mathematics teachers reported feeling at least fairly well prepared to encourage the participation of females (ranging from 92 to 95 percent, depending on grade range), to encourage the participation of minorities (83 to 84 percent), and to teach students from a variety of cultural backgrounds (63 to 73 percent). However, only from 25 to 33 percent feel well prepared to teach students who have limited English proficiency. Similarly, while the great majority of teachers can be expected to have students with one or more learning disabilities in their classes sometime in their career, relatively few teachers, especially at the high school, feel qualified to teach these students.

Note that high school teachers are less likely than their elementary and middle grade counterparts to feel well prepared to use manipulatives and cooperative learning groups as instructional strategies.

Table 14
Mathematics Teachers Considering Themselves Well Prepared*
for Each of a Number of Tasks

	Percent of Teachers		
	Grades 1–4	Grades 5–8	Grades 9–12
Encourage participation of females in mathematics	95	95	92
Present the applications of mathematics concepts	93	93	87
Manage a class of students who are using manipulatives	90	79	62
Teach groups that are heterogeneous in ability	89	85	71
Use cooperative learning groups	87	82	66
Encourage participation of minorities in mathematics	84	84	83
Take into account students' prior conceptions about mathematics when planning curriculum and instruction	81	76	66
Use the textbook as a resource rather than as the primary instructional tool	79	67	62
Integrate mathematics with other subject areas	78	70	50
Use a variety of assessment strategies	77	73	67
Teach students from a variety of cultural backgrounds	70	73	63
Involve parents in the mathematics education of their children	67	57	49
Use performance-based assessment	61	63	58
Use computers as an integral part of mathematics instruction	51	48	43
Use calculators as an integral part of mathematics instruction	55	71	81
Teach students who have learning disabilities	52	43	28
Teach students who have limited English proficiency	28	33	25

* Includes teachers responding "very well prepared" and "fairly well prepared."

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E. The School as a Collegial Work Place

The NCTM *Professional Standards for Teaching* describe a vision for teaching in which teachers are treated as professionals—respected for their expertise, allowed to exercise their professional judgement, and provided ample opportunities to work collaboratively with their peers and to continue to learn throughout their careers.

Mathematics teacher perceptions on issues related to collegiality are shown in Table 15. On the positive side, most mathematics teachers in each grade range feel supported by their colleagues to try out new ideas in teaching (from 80 to 84 percent); indicate that teachers in their school share ideas and materials on a regular basis (52 to 67 percent); and feel that they have many opportunities to learn new things in their job (57 to 76 percent). Similarly, most mathematics teachers feel supported by their administrators. However, fewer than 1 in 5 have time during the regular school week to work with their peers on mathematics curriculum and instruction and only about 1 in 8 indicated that mathematics teachers in their school regularly observe each other teaching classes as part of sharing and improving instructional strategies. The picture that emerges is one where teachers feel supported by their colleagues, but have to "steal" moments to work with them.

Table 15
Mathematics Teachers Agreeing* with Each of a Number of Statements Related to Teacher Collegiality

	Percent of Teachers		
	Grades 1–4	Grades 5–8	Grades 9–12
I feel supported by colleagues to try out new ideas in teaching mathematics	84	83	80
I feel that I have many opportunities to learn new things in my present job	76	72	57
Mathematics teachers in this school regularly share ideas and materials	65	52	67
Most mathematics teachers in this school contribute actively to making decisions about the mathematics curriculum	47	46	69
I have time during the regular school week to work with my peers on mathematics curriculum and instruction	21	17	16
I receive little support from the school administration for teaching mathematics	14	19	20
Mathematics teachers in this school regularly observe each other teaching classes as part of sharing and improving instructional strategies	12	10	11
I am required to follow rules at this school that conflict with my best professional judgment	10	14	16

* Includes teachers indicating "strongly agree" and "agree" to each statement.

F. Conclusion

The results of the 1993 National Survey of Science and Mathematics Education indicate quite different patterns of strengths and weaknesses at different levels of schooling. While elementary teachers tend to be confident in their ability to use reform-oriented strategies, such as cooperative learning, they are not well-prepared to teach a number of mathematics content areas recommended for the early grades. In contrast, high school teachers are more likely to have extensive preparation in mathematics, but are less supportive of the use of reform-oriented instructional techniques and less confident of their ability to do so.

In the short run, greatly increased opportunities for high-quality in-service education are essential to meet the needs of the many mathematics teachers who are not prepared to implement the NCTM *Standards*. At the same time, while there will always be a need for continuing education for teachers, as for any professional, it is clear that substantial changes are needed in pre-service education if future generations of teachers are to be prepared to teach mathematics as envisioned in the *Standards*.

Teachers will also need time to work individually and with their colleagues in implementing mathematics education reforms. The 1993 National Survey of Science and Mathematics Education found that while most mathematics teachers at all levels feel supported by their colleagues to try out new ideas in teaching and regularly share ideas and materials with others in their school, few have time to work with peers during the regular school week. Clearly, the kind of reflective, collegial workplace called for by the NCTM *Standards* will require substantial changes in the structure of schools and schooling.